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Detectability and Effectiveness of the Wide Area Mine

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Four separate studies were conducted by faculty and students of the Department of Systems Engineering, United States Military Academy under the auspices of an Advanced Individual Study in Systems Engineering course. These studies were conducted to assist the U.S. Army Engineering Center and School (USAECS) in studies to assess the effectiveness and doctrine for deployment of the wide area mine (WAM). This report presents a summary of these four efforts.

Specifically, these studies were performed to 1)develop techniques to represent the WAM in the JANUS combat simulation model, 2) evaluate two deployment patterns using JANUS, 3)determine whether indirect fire can be used to defeat WAM, and 4) develop a high resolution simulation to assess deployment patterns to supplement the JANUS results.

A southwest Asian scenario centered around a Soviet style Motorized Rifle Regiment for the Red forces was used for the three JANUS efforts. The blue forces were comprised solely of 180 WAM's (the number organic to armor or infantry battalions). The high resolution model results were derived from a BASIC computer program written to assess deployment patterns. All of these studies were conducted using unclassified data.

These four studies showed that the technique used to represent the WAM in the JANUS model can drastically affect the estimated effectiveness of the WAM. A methodology is presented the produces the most "reasonable" results. The deployability studies produced conflicting results. The JANUS results showed that the X-pattern proved to be more effective in defeating a red force than a random deployment of WAM's for an unknown avenue of approach. However, the high resolution simulation showed the X-pattern did not provide dramatic improvement over some other types of results. Though inconclusive, using JANUS for this type of study was shown to be inappropriate because of the stochastic nature of the problem. Lastly, indirect fire was shown to have little effects in defeating a WAM minefield.

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Acknowledgments

As part of the cadet education process, students and faculty of the Department of Systems Engineering (DSE), United States Military Academy (USMA), West Point, New York, performed analytical studies to support combat effectiveness and deployment options for the Wide Area Mine (WAM). Specifically, under the auspices of an Advanced Individual Study in Systems Engineering course, cadets and faculty performed research to expose cadets to "real-world" Department of the Army (DA) problems. This work was conducted under the direction of the U.S. Army Engineer Center and School (USAECS), Fort Leonard Wood, Missouri.

This work documented herein was conducted by 2Lts Patton S. Gade, John R. Petty, and Stephen R. McIntyre under the direction of Dr. John V. Farr, DSE, USMA. In addition, Dr. Donald R. Barr, DSE, performed some additional analysis in support of the study. This work was conducted under the general supervision of COL James L. Kays, PhD, Professor and Head, DSE, USMA, and BG Gerald E. Galloway, Jr., Dean of the Academic Board, USMA.

MAJ Mark Tillman, DSE, provided technical oversight of the JANUS portion of the study. Dr. Farr wrote this report. CPT Doug Wojcik was the technical monitor of this study at the USAECS. Dr. Barr, MAJ Tillman, and CPT Wojcik reviewed this report.

This work was conducted during the period 18 January 1994 through 1 July 1994. The methodology and results contained herein are not to be construed as official DA or Department of Defense (DoD) position, policy, or decision. The methodology and results contained herein are solely the responsibility of the authors.

Executive Summary

Four separate studies were conducted by faculty and students of the Department of Systems Engineering, United States Military Academy under the auspices of an Advanced Individual Study in Systems Engineering course. These studies were conducted to assist the U.S. Army Engineer Center and School (USAECS) in studies to assess the effectiveness and doctrine for deployment of the wide area mine (WAM). This report presents a summary of these four efforts.

Specifically, these studies were performed to

- develop techniques to represent the WAM in the JANUS combat simulation model,
- evaluate two deployment patterns using JANUS,
- determine whether indirect fire can be used to defeat WAM, and
- develop a high resolution simulation to assess deployment patterns to supplement the JANUS results.

A southwest Asian scenario centered around a Soviet style Motorized Rifle Regiment for the Red forces was used for the three JANUS efforts. The blue forces were comprised solely of 180 WAMs (the number organic to armor or infantry battalions). The high resolution model results were derived from a BASIC computer program written to assess deployment patterns. All of the studies were conducted using unclassified data.

These four studies showed that the technique used to represent the WAM in the JANUS model can drastically affect the estimated effectiveness of the WAM. A methodology is presented the produces the most "reasonable" results. The deployability studies produced conflicting results. The JANUS results showed that the X-pattern proved to be more effective in defeating a red force than a random deployment of WAMs for an unknown avenue of approach. However, the high resolution simulation showed that the X-pattern did not provide a dramatic improvement over some other types of results. Though inconclusive, using JANUS for this type of study was shown to be inappropriate because of the stochastic nature of the problem. Lastly, indirect fire was shown to have little effects in defeating a WAM minefield.

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Detectability and Effectiveness of the Wide Area Mine

1. Introduction

1.1 Background

The mission of the Wide Area Mine (WAM; see Figure 1.1 for an artist rendition of the WAM) is to increase the effectiveness of minefields, slow mine clearing operations by attacking enemy countermine vehicles, and disrupt enemy formations and command and control forward of most direct fire systems. In addition, the WAM can be deployed deep behind enemy lines and used to disrupt combat service support operations and used to protect troop flanks against armor and other vehicles (from ARDEC, 1993). Presently, the main advantage of the WAM over a conventional minefield is reduced logistical support. Because the WAM has a circular footprint of roughly 200 meters in diameter, one WAM can replace many conventional mines and thus reduce logistical support. This concept is shown in Figure 1.2. Future generations of the WAM will serve many roles in addition to a smart munition. For example, because the WAM can categorize vehicles, one of it's primary roles will be as an intelligence asset.

The WAM operates by launching a top attack submunition against nearby enemy vehicles. The WAM's seismic and acoustic sensor searches out target vehicles within a range of 100 meters, locates them, and then launches a submunition. As the submunition flies over the target, a two color infrared (IR) sensor detects the target and fires an explosively formed penetrator (EFP) at the top of the target (from ARDEC, 1993). This concept is illustrated in Figure 1.3.

The WAM will be shipped on six pallets consisting of 30 mines each. This corresponds to the hauling capacity of a heavy expanded mobility tactical truck or HEMTT. These 180 mines are the projected number of WAMs that will be allocated to a U. S. Army infantry or armor battalion for a normal defensive mission.

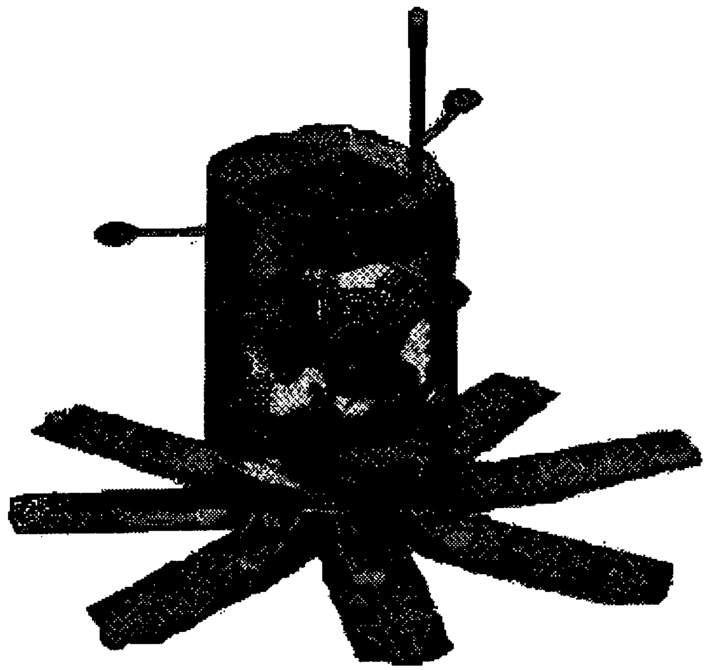


Figure 1.1 Artist rendition of the WAM (from Army Times, 1992)

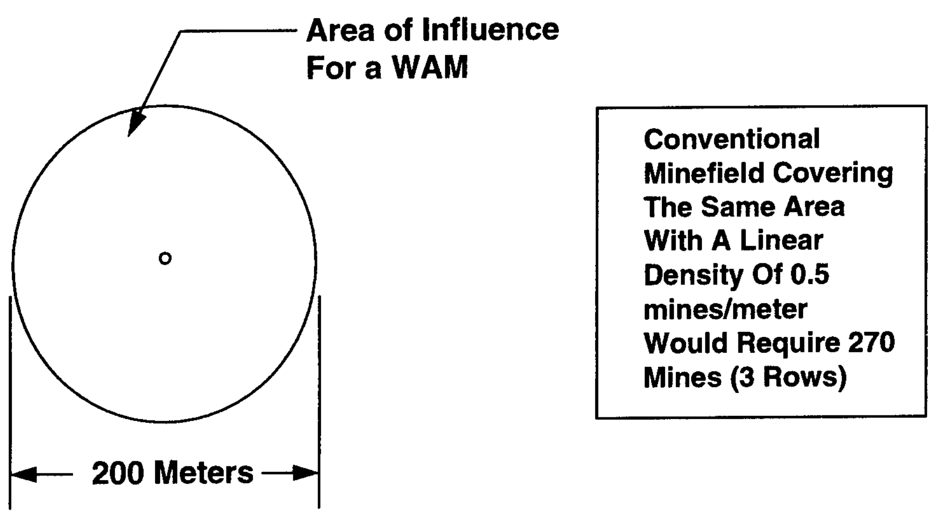


Figure 1.2 Conventional minefield versus WAM operations

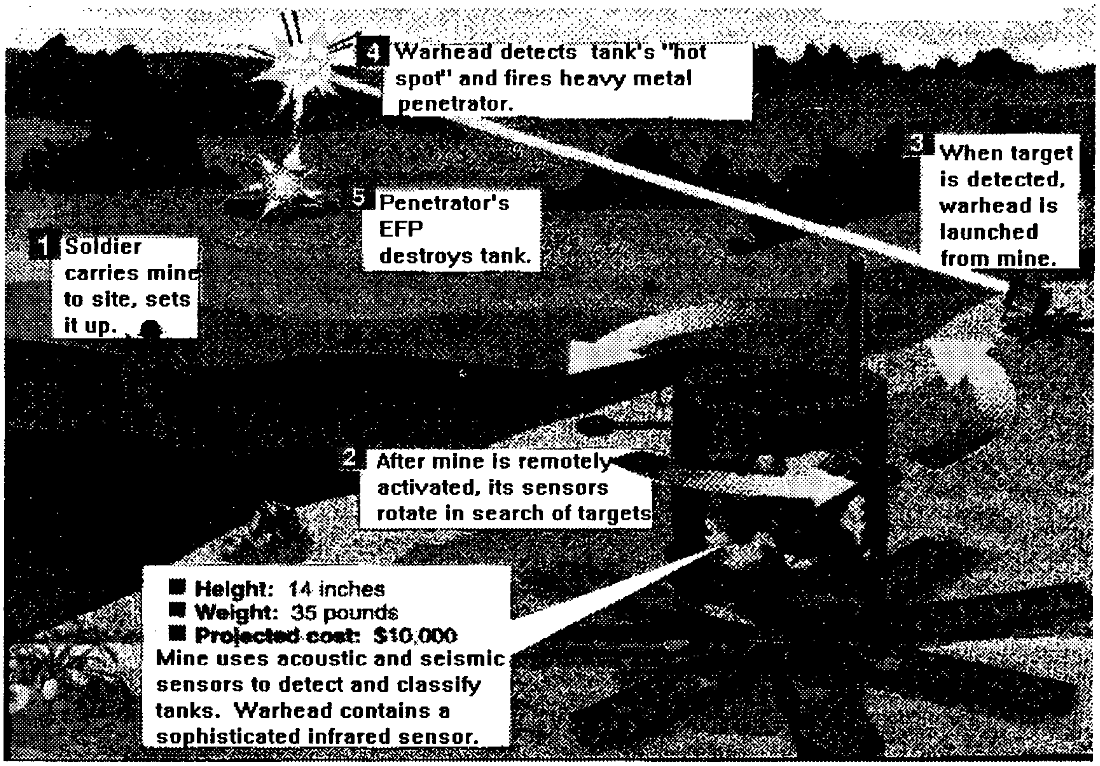


Figure 1.2 Operational concept for deployment of the hand emplaced WAM (from Army Times, 1992)

The major characteristics of the WAM are:

- weight of 35 pounds,
- height of 14 inches,
- cost of $30,000,
- soldier emplaced,
- armed manually or remotely, and
- contains a self destruction mechanism.

In future generation of the WAM, it will have the ability to be turned off and on in order to allow friendly vehicles to pass through the minefield. The WAM can also be programmed to allow the first column of enemy vehicles to pass through the minefield in order to destroy more vehicles before they have the ability to react.

This report documents the results of four studies conducted under the direction of the U.S. Army Engineer Center and School (USAECS). These studies were performed to support effectiveness studies and deployment doctrine for the WAM. Specifically, these studies addressed how

- to properly portray the detectability of WAM in the JANUS combat simulation model,
- to deploy the WAM in an area disruption situation using based upon results from JANUS and other high resolution model results, and
- whether indirect fire (i.e., artillery) can be used in defeating or reducing the effectiveness of a WAM minefield.

1.2 Scope

This report contains seven main chapters and two appendices. Chapter 1 contains the introduction and scope. Chapter 2 contains details of the scenario used for the WAM studies. This chapter contains the location, force structure, physical characteristics, etc., that comprise the scenario used for the results presented in Chapters 3, 4, and 5. In addition, a section is devoted to the significant measures of effectiveness (MOE) used in all JANUS related efforts. Chapter 3 contains the results of a study to quantify how to properly portray the detectability of WAM in the JANUS combat simulation model. Chapter 4 presents the results of a JANUS study in how to deploy the WAM in an area disruption situation. Chapter 5 presents the results of a JANUS study on the effects of indirect fire on defeating a WAM minefield. Chapter 6 presents the results of a high resolution model to supplement the JANUS result for deployability doctrine for area disruption. Chapter 7 contains the summary and conclusions. The two appendices contains an acronyms and abbreviations and a BASIC source code listing for the high resolution WAM deployability analysis model.

2. Scenario

2.1 Introduction

A southwest Asian (SWA) scenario was used for the three JANUS related studies (i.e., detectability, patterns for area disruption, and artillery clearing of WAM). The terrain is ideal for optimum deployment of the WAM because of the lack of vegetation and the uniformity of the soil. Specifically, the 73 Easting terrain located in southeastern Iraq was used. A Soviet style Motorized Rifle Regiment (MRR) was used as representative of the threat forces. No covering fire was employed. Friendly forces consisted solely of 180 stationary WAMs deployed in two different patterns.

2.2 Terrain

The terrain used is representative of most SWA desert environments with very little vegetation. The landforms can be classed as plains with minimum local relief. The sparse vegetation and minimal relief contribute to maximum mobility and weapons effectiveness. The 73 Easting terrain file contains about 100 by 100 kilometers of data as shown in Figure 2.1. The scenario was played out across approximately 15 kilometers of that terrain. Note that the contour intervals shown in Figure 2.1 are at 30 meters.

2.3 Red Force Structure

A Soviet style MRR force advancing in a movement to contact doctrinal formation as shown in Figure 2.2 was used as representative of a typical threat force. All vehicles are either a T-80, BMP-1, or BMP-2. The formation continues through the minefield once the WAMs are encountered similar to a "bull through" doctrine. The JANUS data files containing weapons characteristics were taken from the standard unclassified Training and Doctrine Command (TRADOC) data base.

2.4 Blue Force Structure

With the exception of the artillery assets required for the third study, the blue forces employed consisted solely of WAMs. Two patterns were used as part of the patterns for area disruption study. The first pattern consists of WAMs deployed in an X pattern and is shown in Figures 2.3. The other pattern

consisted of 20 mines randomly deployed in a 1 square km grid cell. Note that none of the WAMs 200 meter foot print overlapped for the random pattern.

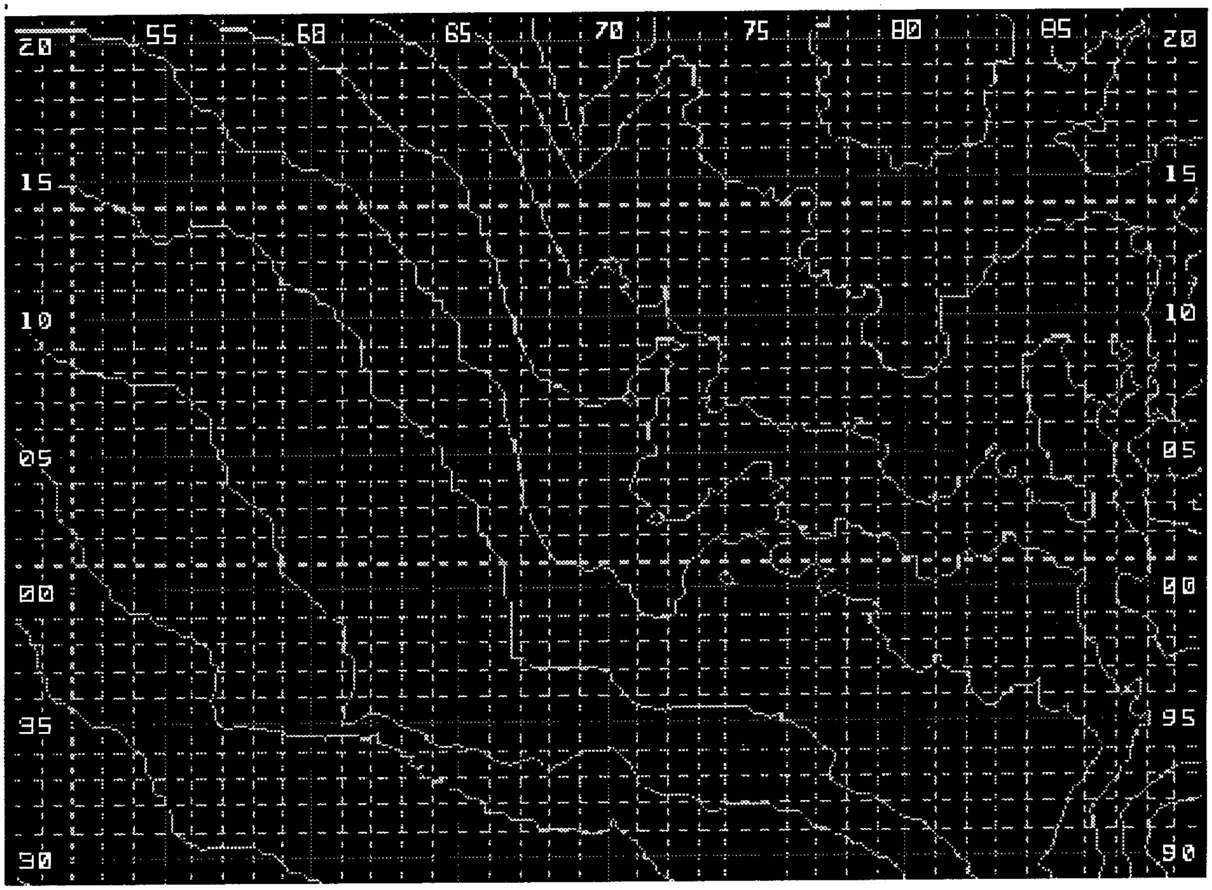


Figure 2.1 Location of 73 Easting terrain

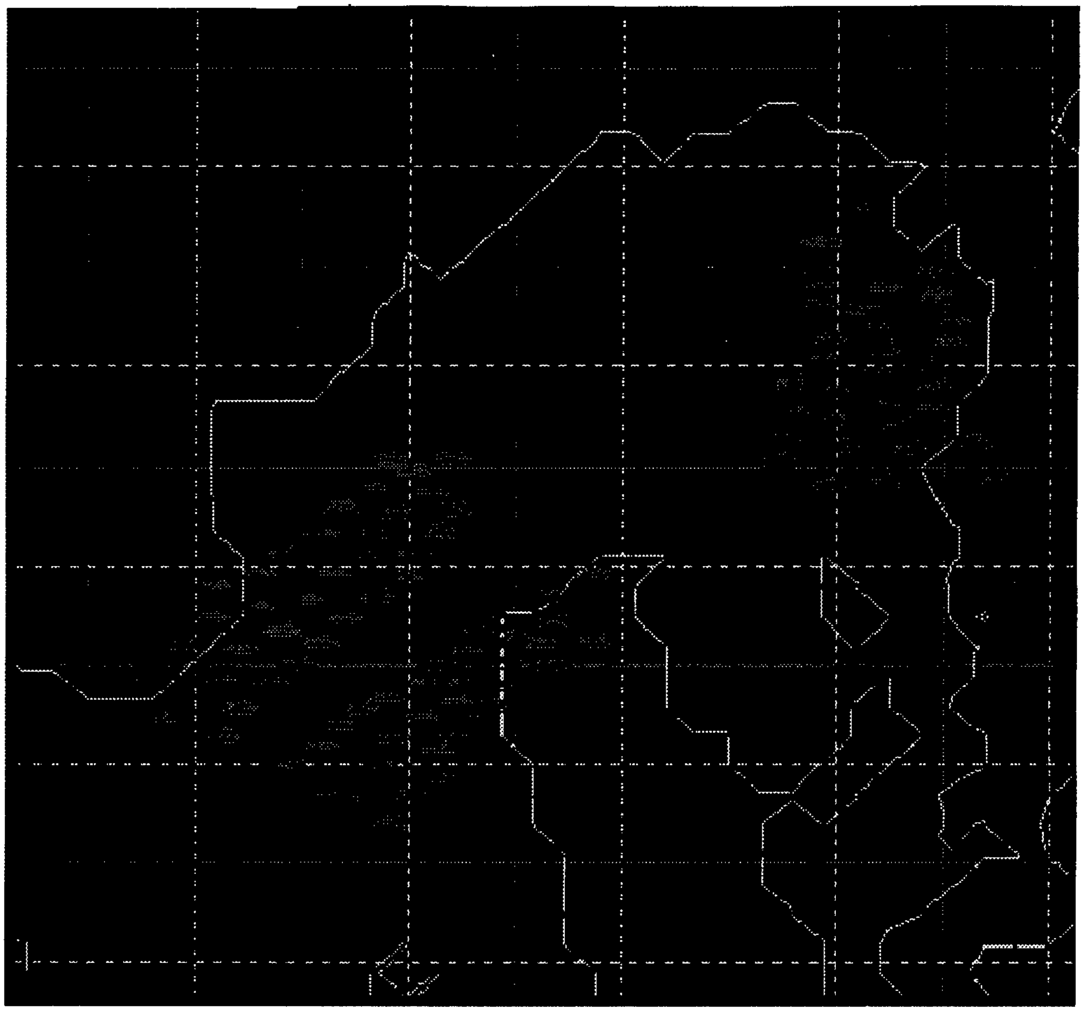


Figure 2.2 Soviet style MRR advancing in a movement to contact formation

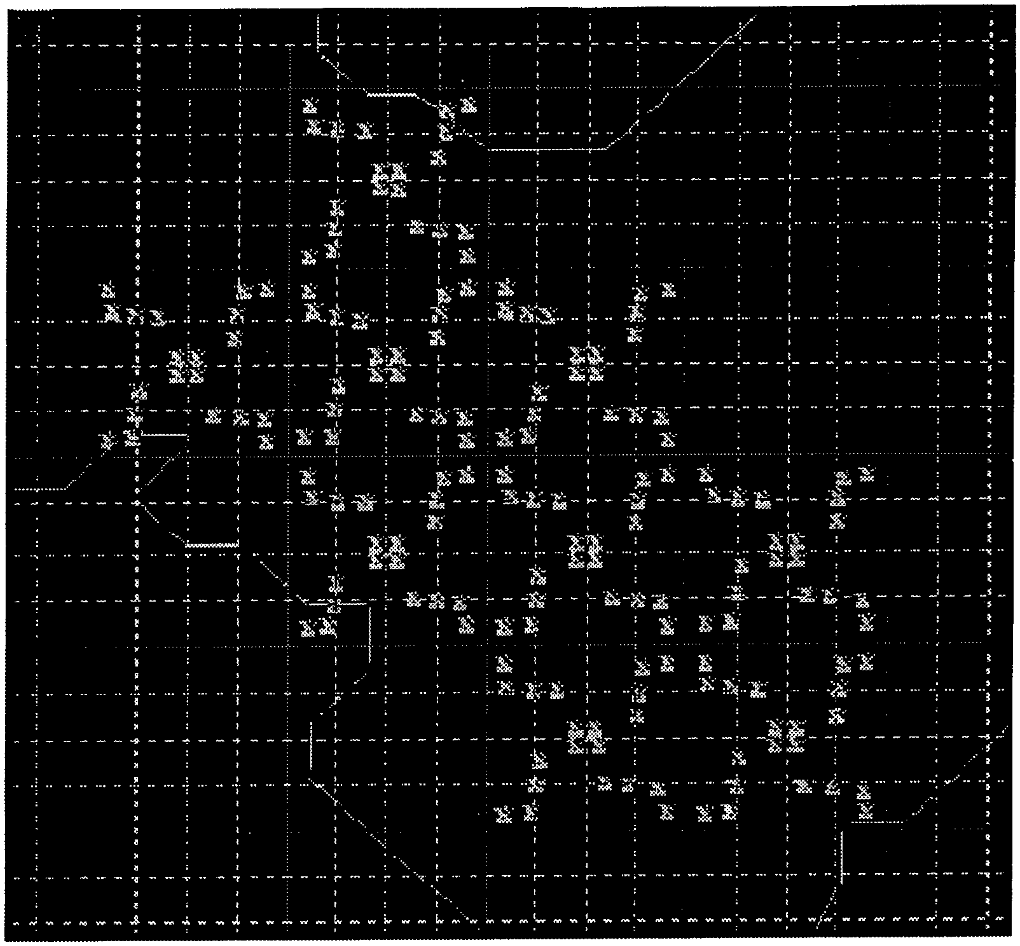


Figure 2.3 WAM X-pattern

2.5 Significant MOE

Several standard major measures of effectiveness (MOE) were used in the studies. These include:

<u>Fractional Exchange Ratio (FER)</u> - A normalized comparison between the losses of the two sides is made. Since WAM is only deployed on one side, this is a measure of how well WAMs survive relative to their initial number. A value greater than one implies that WAMs are killing a larger percentage of enemy vehicles relative to the percentage of WAMs killed. This MOE can be expressed in equation form as

$$\text{FER} = \frac{\dfrac{\text{Number of Red Equipment Losses}}{\text{Initial Red Strength}}}{\dfrac{\text{Number of Blue Equipment Losses}}{\text{Initial Blue Strength}}} \tag{2.1}$$

Loss Exchange Ration (LER) - This MOE does not account for the initial strength of the forces. This is purely a ratio of the number of kills. An LER of greater that one implies that fewer WAMs were killed than the enemy forces. This MOE can be expressed in equation form as

$$\text{LER} = \frac{\text{Number of Red Losses}}{\text{Number of Blue Losses}} \tag{2.2}$$

Percent of Red Kills - This MOE is similar to LER, however, it does not conclude a comparison to the initial blue strength. This MOE provides insight into the lethality of the WAM. The higher the number the better.

Average Detection Range - An MOE based upon average detection range is important to insure that the WAM is being properly portrayed.

Average Kill Range - The average kill range is the sum of the kill ranges divided by the total number of kills. This measure can have a value of zero or any positive number. This MOE will show how close the enemy gets to the WAMs before they are able to kill them. The converse, the kill range of the enemy killing the WAM, is an important MOE too.

Other specialty MOE are used in this report. If different than those previously discussed, they will be defined.

The FER and LER are probably not good measures of combat effectiveness for the WAM because 1) WAMs are inexpensive unmanned munitions and 2) in reality WAMs are expended (i.e., killed) when they engage a target. However, those results are presented because they are standard MOEs for combat effectiveness.

3. Detectability of WAM

3.1 Introduction

To support the effectiveness analysis and deployability studies, the true behavior of the WAM should be captured in a combat simulation model. Most of these types of studies are performed in either JANUS or Combined Arms Support Task Force Model (CASTFOREM) to capture the resolution required for the system. For these high resolution studies, the detectability of the WAM is an important input parameter. The size of the WAM makes it vulnerable to enemy detection and if it can be detected, it can be destroyed by small arms fire. A high detectability or acquisition by the red forces causes the WAM to have little effect on the battlefield in a combat simulation model. Conversely, if a low detectability is used, the WAM becomes a lethal weapon that sustains few kills on the battlefield. We hypothesize that both of these are unrealistic representations.

A sensitivity analysis varying the height of the WAM was conducted in the JANUS model with the hope of developing a methodology to accurately portray the detectability of the WAM. The actual height of the WAM is about 0.25 meters. This value was originally used in JANUS. However, sensitivity analyses were performed in an effort to accurately capture the detectability properties of the WAM. Since this value is the main input number that affects detectability, a sensitivity analysis of its' effect on JANUS runs was critical to obtaining meaningful results.

3.2 Input Data

In order to create an adequate model of the WAM in JANUS, several of the functions of the WAM were approximated. For instance, the WAM has a seismic sensor that allows it to interpret ground vibrations and differentiate between different types of vehicles. Using this seismic sensor, the WAM has the ability to detect enemy forces up to 400 meters away depending upon environmental conditions. This allows the WAM time to track the enemy vehicles before they enter the 100 meter kill radius of the WAM. JANUS does not have the ability to represent a seismic sensor and its associated characteristics. Therefore, the seismic sensor was modeled as a visual sensor. However, to ensure that the visual sensor would be able to "see" over terrain to replicate the ground sensing technique employed by the WAM, the visual sensor was set on a 20 meters mast. This allows JANUS to see over terrain that the actual seismic sensor would be able to hear through . Though appropriate for the desert environment, this concept and mast height might not be suitable for dense vegetation.

Also, the WAM was modeled as having no thermal signature, no audio signature, and being unable to move. Any thermal or audio signature in JANUS would make the WAM much easier to detect and would not accurately portray the detectability properties of the WAM.

Several different probability of hit/probability of kill (Ph/Pk) tables had to be generated in order to model the WAMs interaction with enemy vehicles. For the sake of simplicity, one set of Ph/Pk value data was used for different types of targets. In order to produce unclassified results, the published single shot Ph/Pk of 0.3 was generalized as shown in Table 3.1

Table 3.1 Ph/Pk data for the WAM against all vehicles

	50 Meters	**100 Meters**
Ph	0.3	0.25
Pk	1.0	1.0

In addition, Ph/Pk data for enemy weapons shooting at the WAM was required to conduct the study. The two major weapons used to defeat the WAM were 7.62 mm and 12.7 mm machine guns. These are the weapons that can be found on the BMP-1, BMP-2, and the T-80 tank. The Ph/Pk data used in the study for these weapons against the WAM are shown in Table 3.2.

Table 3.2 Ph/Pk data for the 7.62 mm and 12.7 mm machine guns against the WAM

a. 7.62 mm machine gun

Range	0	400	600	800	1200
Ph	0.2	0.15	0.1	0.08	0.04
Pk	0.9	0.8	0.7	0.6	0.4

a. 12.7 mm machine gun

Range	**0**	**800**	**1200**	**2000**
Ph	0.235	0.15	0.1	0.0125
Pk	0.9	0.6	0.5	0.3

Actual data does not exists for the enemy Ph/Pk when shooting at the WAM. Therefore, these estimates were derived assuming that the WAM is approximately as vulnerable to enemy fire as is a soldier. Since the WAM is approximately one fifth the size of a soldier, the vulnerability of the WAM was assumed to be that of a soldier. However, the WAM is more vulnerable than a soldier because a bullet

landing near by may kick rocks and other debris into the WAM, thus affecting its ability acquire, categorize, and kill. For this reason, the Ph/Pk table values from the enemy weapons shooting at a soldier were divided by four for the study instead of 5.

Once the WAM was modeled in JANUS, preliminary runs were made to test the WAM behavior in JANUS. Initially, the enemy was not allowed to shoot at the WAMs (i.e., height of 0 meters). This resulted in the majority of the enemy forces being destroyed by the WAMs. Believing that this result was not realistic, the enemy was allowed to shoot at the WAMs using the parameters previously discussed (i.e., height of 0.25 meters). This also produced unrealistic results. The enemy forces were able to destroy nearly all of the WAMs from distances of up to 2 kilometers away. Thus, data had to be adjusted to produce more realistic model results. The easiest parameter to alter in this model was the size of the WAM. When the size of the WAM was modeled with a height of 0.25 meters, the probability of acquiring the WAM was very high, even from far away. Based upon discussions with soldiers familiar with the M1A1 tank, it is not unrealistic given today's high technology for a tanker to see a 14-inch tall WAM from a kilometer away. However, they all agreed that given the "fog of war", they would probably be looking for a larger target such as an enemy tank. Since JANUS cannot model the "fog of war", it was necessary to reduce the size of the WAM to produce more realistic results. Figure 3.1 shows a graph of range versus the probability of detection for a 0.25 meter tall WAM. As shown in that figure, the enemy has a 0.5 probability of detecting the WAM from 500 meters away. Since it can be detected from such a large distance, the WAM can be destroyed before encountering the 100 meter foot print. By adjusting the size of the WAM and producing similar graphs, a WAM size to be inputted into JANUS was developed which produced more realistic survivability characteristics. An optimum height of 0.08 meters was chosen. A graph of the range versus the probability of detection is shown in Figure 3.2.

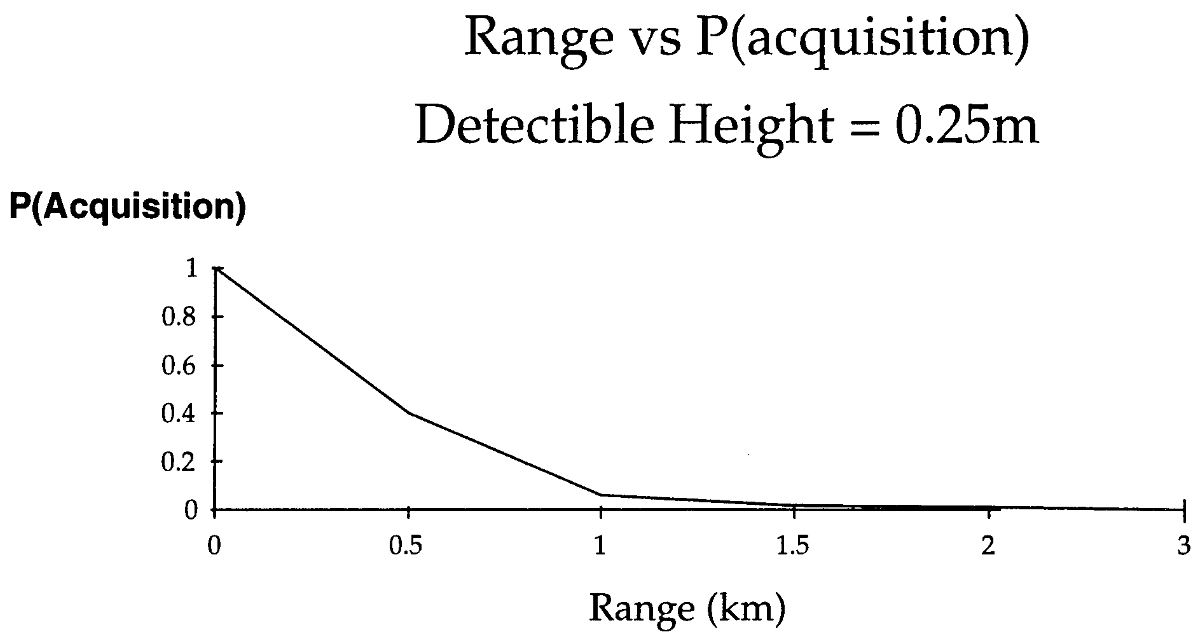


Figure 3.1 Range versus probability of detection for a 0.25 meter tall WAM

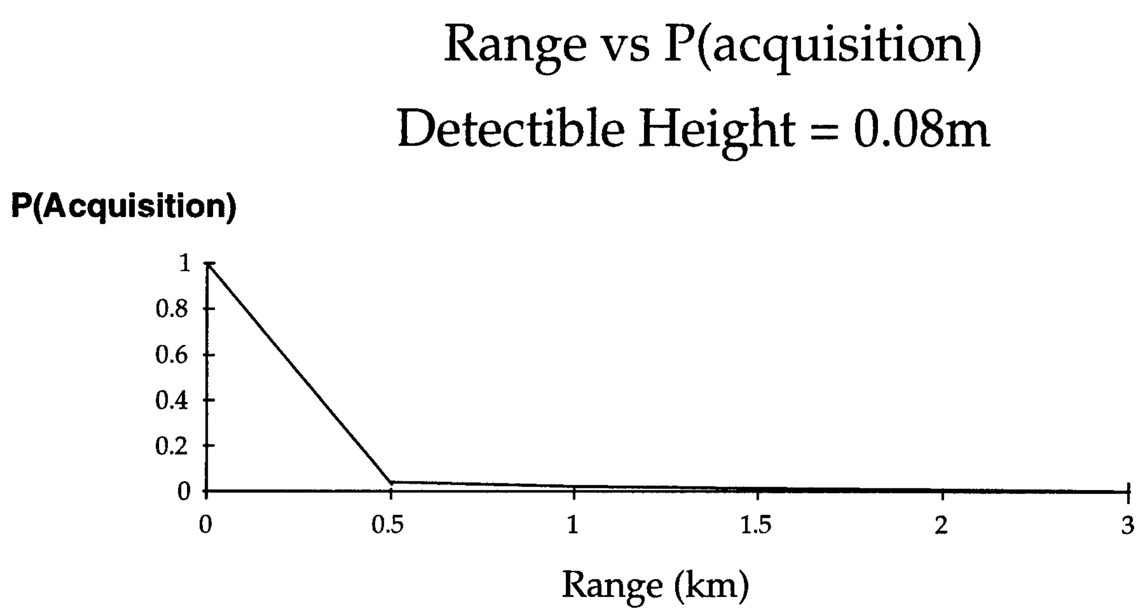


Figure 3.2 Range versus probability of detection for a 0.08 meter tall WAM

Numerous JANUS simulations were conducted to ensure that a WAM height of 0.08 meters produced realistic results. All of the MOE discussed in Chapter 2 were analyzed in support of the analysis.

3.3 JANUS Model Results

A graph of the number of WAMs and enemy forces (i.e., vehicles) killed for each of the different areas are shown in Figure 3.3. As shown in that figure and as previously discussed, 0 (not allowing the enemy to shoot the WAM) and 0.25 meter (actual height) detectable heights, produce representations of a best and worst case scenario. The model that produces the most realistic representation uses a detectable height of 0.08 meters.

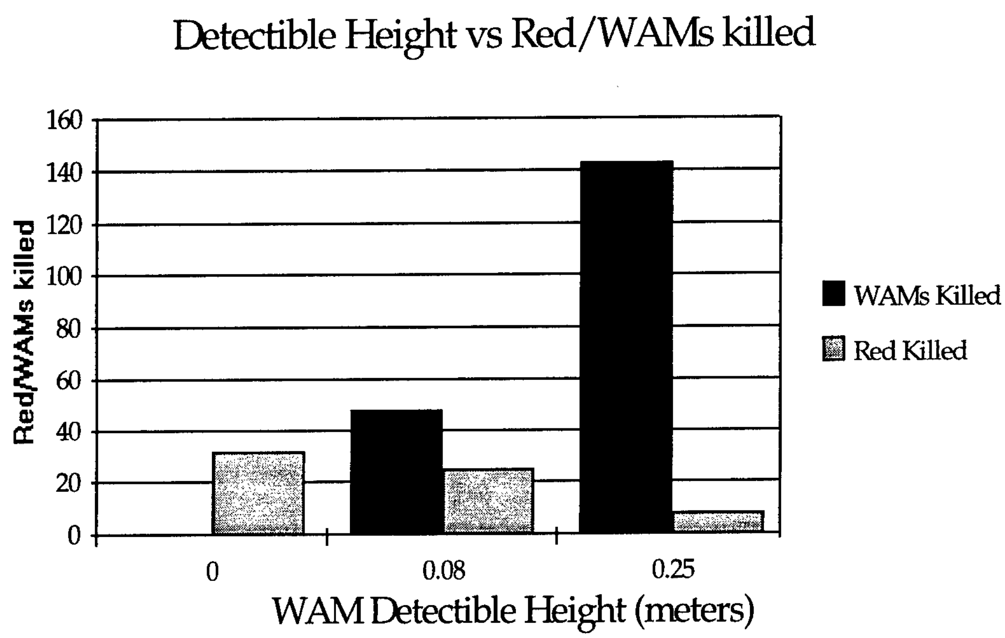


Figure 3.3 Model results as a function of WAM height against the X-pattern

The representation of the WAM is important because the area disruption study required this input value to produce meaningful results.

4. WAM Patterns for Area Disruption

4.1 Introduction

In order to support fielding of the WAM, studies are needed to determine how to best deploy the WAM for various tactical scenarios. This study was undertaken to determine if results from the JANUS combat simulation model could be used to determine deployment patterns. Early in the study it was recognized that JANUS was probably not the proper tool to perform this type of study. Thus, a high resolution study (see Chapter 6) was initiated. However, because JANUS is recognized as an acceptable model at DA and DoD for COEAs and other types of studies, the study was performed to see if useful information could be obtained.

If 20 WAMs are to be deployed in a 1 km square area (see Figures 2.3), this is roughly equal to the size of a conventional minefield group. Consistent with engineering doctrine, minefield belts are designed to disrupt, turn, fix, or block (see FM 20-32) the enemy. Specifically, this study addressed the optimal deployability pattern for fixing the enemy. Typically, a fixing minefield has the characteristics shown in Figure 4.1

Group Dimensions	**1.0 W x 1.0 D**
Probability of Kill	**50 %**
Frontage - Minefield	**250 m**
Depth - Minefield	**120 m**
Anti Tank Mines	**Yes**
Anit Personnel Mines	**No**

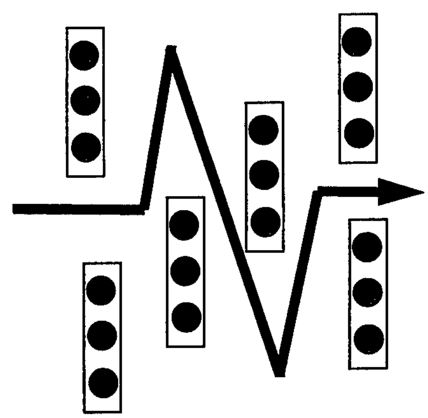


Figure 4.1 Characteristics of a fixing minefield group

4.2 Input Data

Characteristics of the terrain, opposing force, and WAM have been previously been described in Chapters 2 and 3. Two design points were used to assess how WAM patterns affected effectiveness. Table 4.1 shows the two design points.

Table 4.1 Two point design for WAM pattern study

Design Point	WAM Pattern
1	random
2	X

The WAM X pattern is shown in Figure 2.3. The random pattern consisted of randomly placing the same number of WAMs in the same grid cells as shown in Figure 2.3. No overlapping of the 200 meter WAM footprint was allowed. The individual WAMs were simply located using the interactive capabilities of JANUS. Thus, some variation can exist between 1 km cells.

4.3 JANUS Model Results

Model results are presented in Table 4.2 for nine MOEs. This table shows the design point (DP), results for that MOE, and some statistical interpretation based upon t distribution results. The GO and NO GO designators indicate whether there is enough difference between the factor levels to indicate a difference beyond what is due to chance given the small sample size (i.e., 5 for each design point for a total of 10 runs). A significant amount of difference did exist between the X and random patterns for some individual runs. However, with the exception of the FER, LER, number of WAMs killed, and percent of WAMs killed, differences for the average values for the five runs were not discernible. The most important MOE, number of red systems killed, did not produce a major difference between the effectiveness of the two patterns.

Table 4.2 JANUS model results for the area denial study

a. FER of the total force MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.29	0.24	0.31	0.19	0.21
2		x		0.3	0.72	0.43	0.34	0.28
alpha	0.2							
t-value	1.533206		Difference	0.01	0.47	0.12	0.14	0.07
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	0.162	0.006434	0.122982	0.284982	0.039018	GO		

b. LER OF WAM MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.65	0.53	0.7	0.43	0.47
2		x		0.68	1.6	0.95	0.76	0.63
alpha	0.2							
t-value	1.533206		Difference	0.03	1.05	0.25	0.305	0.16
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	0.359	0.032006	0.274294	0.633294	0.084706	GO		

c. Average detection range for the WAM MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.079	0.071	0.077	0.077	0.077
2		x		0.079	0.084	0.074	0.085	0.08
alpha	0.2							
t-value	1.533206		Difference	0	0.013	-0.003	0.008	0.003
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	0.0042	8.14E-06	0.004374	0.008574	-0.000174	NO GO		

d. Average Kill Range for the WAM MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.078	0.074	0.076	0.078	0.075
2		x		0.075	0.078	0.082	0.075	0.076
alpha	0.2							
t-value	1.533206		Difference	-0.003	0.0035	0.006	-0.003	0.004
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	0.0015	3.55E-06	0.002889	0.004389	-0.001389	NO GO		

e. Average detection range for red systems MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.144	0.138	0.147	0.15	0.148
2		x		0.153	0.135	0.141	0.138	0.143
alpha	0.2							
t-value	1.885619		Difference	0.0085	-0.0035	-0.006	-0.0115	-0.005
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	-0.0035	1.08E-05	0.006204	0.002704	-0.009704	NO GO		

f. Average kill range for red systems MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.15	0.148	0.159	0.135	0.137
2		x		0.151	0.143	0.143	0.128	0.146
alpha	0.2							
t-value	1.533206		Difference	0.001	-0.01	-0.016	-0.007	0.009
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	-0.0046	1.91E-05	0.006694	0.002094	-0.011294	NO GO		

g. Number of WAMs killed MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		65	55	63	63	55
2		x		47	43	43	41	65
alpha	0.2							
t-value	1.533206		Difference	-18	-12	-20	-22	10
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	-12.4	34.16	8.961059	-3.438941	-21.36106	GO		

h. Number of red systems killed MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		42	29	44	27	26
2		x		32	69	41	31	41
alpha	0.2							
t-value	1.533206		Difference	-10	39	-3	3	15
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	8.8	73.84	13.17487	21.97487	-4.374868	NO GO		

i. Percent of WAMs killed MOE

DP		Pattern		Run1	Run2	Run3	Run4	Run5
1		random		0.361111	0.305556	0.35	0.35	0.305556
2		x		0.261111	0.238889	0.238889	0.227778	0.361111
alpha	0.2							
t-value	1.533206		Difference	-0.1	-0.066667	-0.111111	-0.122222	0.055556
	Average							
	Difference	VAR	1/2 length	Upper	Lower			
Pattern	-0.068889	0.001054	0.049784	-0.019105	-0.118673	GO		

The results presented are inconclusive. Given the problems encountered with trying to properly portray the WAM in JANUS, this is not unexpected. Any differences between the X-pattern and the random pattern are probably more a product of the scripting of the scenario. If the angle of approach had been varied, significant differences between the effectiveness of the two patterns may or may not have existed.

5. Indirect Fire Effects on the WAM

5.1 Introduction

One of the many issues facing the deployment of WAM centers around survivability. By design, the WAM focuses on lethality and not survivability of itself during combat. However, as is well known, the more survivable a weapons system, the higher the probability it has to exercise its' ability to kill upon the battlefield.

One particular area of interest is the WAM's survivability while under indirect fire attack. Since indirect fire should be able to destroy the WAM without it being able to affect for example a field artillery (FA) battery, indirect fire could become a counter measure for WAM.

Because of the WAM's small size, it should be relatively invulnerable to indirect fire attack. This has not been verified in independent field tests. Simulations and actual field tests are required to determine what the effect of indirect fire is upon WAM in the total combined warfare aspect of the modern battlefield. In the context of the modern battlefield, some key questions arise:

- Can artillery kill WAM?
- If so, how well?
- Does artillery have any residual benefits on breaching force for a WAM minefield? In other words, does artillery indirectly benefit a breaching force in any way?

In essence, should artillery be employed to defeat WAM and if so how?

Initially, the scope of the problem needed to be defined. What type of artillery should be used? How can WAM and FA effects be modeled in JANUS? Initially, the idea of non conventional rounds was explored. However, for this study, it was decided that only Point Detonating (PD) and Variable Time (VT) Fuze rounds would be used. This is mainly due to the line of reasoning that since we are the only Army with the WAM, we want to know what our potential enemies could do to WAM with their existing artillery. Although some of our potential enemies have non-conventional rounds, most have only have high explosive with a PD fuze or at best, VT fuze rounds. Therefore, we decided to only include analysis pertaining to those types of rounds that might actually be fielded against WAM by enemy forces.

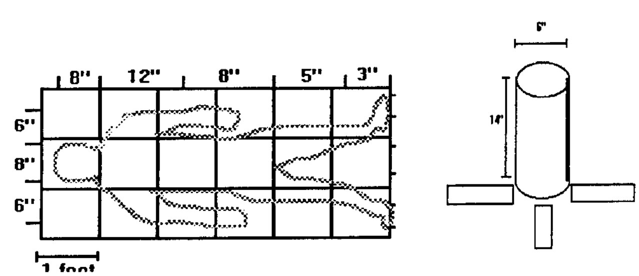
5.2 Input Data

One of the main difficulties in performing an unclassified study is being able to obtain useful data. Specifically, there was no unclassified vulnerability data available. Therefore, some assumptions were made in order to develop input data. Therefore, models and generalizations were used to generate lethal areas that could be entered into JANUS.

Level areas are those areas in which WAM is vulnerable to artillery. JANUS has suitable unclassified data for many different units' vulnerability to indirect fire, among which was the vulnerability of a troop in the prone (TIP) to artillery. This data was used to develop the lethal are for the WAM.

To relate TIP to WAM, it was assumed that the vulnerability of WAM is linearly proportional to the vulnerability of a TIP. This assumption is based on the fact that both a TIP and a WAM suffer similar ground level blast and fragmentation effects from indirect fire. Therefore, the only way that WAM varies from a TIP is by the amount of exposed area that a WAM has in comparison to a TIP.

In order to model the vulnerability to PD rounds, a man 5'9" in height was laid on a grid and his side level exposed area was determined as shown in Figure 5.1. An average was taken for the amount of exposed area from all four sides to arrive at a number for how much side exposed area an average troop has to a ground detonation. This average value was 0.61140 meters^2.



Pd vs WAM: 0.10057 as vulnerable as TIP (10)

VT vs WAM: .02653 as vulnerable as TIP (38)

Figure 5.1 WAM-troop in the prone proportionality study

Next, WAM was estimated to be 14 inches by 6 inches from the side view or 0.06149 square meters. Therefore, the ratio of exposed area of a WAM to a person in the prone was 0.10057, or a troop has 9.94 times as much exposed area as a WAM. Following the earlier linear proportionality assumption, this means that a troop is also 9.94 times as vulnerable to indirect fire as is WAM. Thus, for HE lethalities in JANUS the values listed in the nine vulnerability categories listed for vulnerability of a troop in the prone were divided by 9.94. This will provide, for a given WAM category, vulnerability to indirect point detonating rounds.

Similar methods as discussed above were used to model the vulnerability to VT rounds. The only difference was in perspective from the round. For VT, the top view is of interest. For the troop , the exposed area was estimated at being 0.78006 meters^2 and for WAM, for only the circular top of the mine, 0.02070 meters^2. This gave us a value that a troop in the prone was 37.68769 times as vulnerable to an airburst as the WAM.

Another input parameter required was to determine what type of damage function to use for modeling the effects of artillery against WAM. The JANUS model has two options, the cookie cutter algorithm and the Carleton Damage Function (CDF). The CDF was chosen because of the exponential nature of the P(k) modeling best fit the effects desired. Basically, CDF takes the distance a round falls away from the WAM, and uses an exponential function to determine the probability of kill. It is important to realize at all ranges, a probability of kill exists. Of course, the Pk is greatest at close range. This is a generally accepted way to model artillery effects on soft targets.

The base case for the scenario was the same scenario as previously discussed (i.e., X-pattern using 73 Easting terrain). In order to conduct the artillery analysis, two different scenario modification were made.

<u>Battery Scenario</u> - The first scenario modification was the introduction of a six gun battery of Soviet type 152mm Howitzers. They were placed approximately 8 kilometers away from the WAM minefield that was to be the intended target.

<u>Division Artillery Scenario</u> - The second scenario modification was the introduction of a division artillery asset. This asset was placed in the identical position as the six gun battery and consisted of 72, 152mm Howitzers.

5.3 JANUS Model Results

Once the WAMs and the guns had been placed, the next step was to conduct simulation runs to answer the questions mentioned earlier. It was decide that the simplest and most effective method of answering the questions was to conduct Analysis of Variance (ANOVA) on the simulation response data. The following experiment consisting of five basic scenarios were used and are listed as follows:

1) PD Rounds versus WAM, Six Gun Battery, Six Fire Missions (36 total rounds)

2) PD Rounds versus WAM, Seventy Two Gun Battery, Six Fire Missions (432 total rounds)

3) VT Fuze Rounds versus WAM, Six Gun Battery, Six Fire Missions (36 total rounds)

4) VT Fuze Rounds versus WAM, Seventy Two Gun Battery, Six Fire Missions (432 total rounds)

5) No Artillery Fired

The basic idea behind choosing these five scenarios was that if ANOVA showed that none of the artillery scenarios significantly varied from the non-artillery scenarios, then artillery statistically has no effect on WAM.

Each scenario was replicated six times with different random number seeds so that enough data could be collected for the ANOVA tests. These results are shown in Table 5.1.

Using ANOVA, the above data was analyzed to provide answers to the originally stated questions regarding the effects of artillery on WAM. As stated earlier, ANOVA tests to see if all the means are equal among the different MOE for each set of scenarios. If the analysis concludes in any measure of effectiveness that we "fail to reject" the null hypothesis that all means are equal, then it can be concluded that we have insufficient evidence to conclude a difference exists due to the introduction of artillery. No difference is not rejected.

The MOEs tested are:

- Number of WAMs killed by Artillery
- Number of WAMs killed by Direct Fire
- Number of Red killed by WAM

Table 5.1 Simulation results for PD and VT artillery rounds

Name	Number of Guns	Random Number Seed	WAMs Killed By Direct Fire	WAMs Killed By Artillery	Red Task Force Killed By WAM	Red Task Force Killed By Friendly Fire
PD VS WAM	12	15011	63	0	32	0
PD VS WAM	12	10000	55	0	26	0
PD VS WAM	12	11000	58	0	51	0
PD VS WAM	12	12000	67	0	43	0
PD VS WAM	12	13000	61	0	50	0
PD VS WAM	12	14000	61	0	33	0
PD VS WAM	72	15011	53	1	27	0
PD VS WAM	72	10000	62	8	49	1
PD VS WAM	72	11000	59	0	54	0
PD VS WAM	72	12000	63	5	29	0
PD VS WAM	72	13000	47	1	39	0
PD VS WAM	72	14000	52	1	46	0
VT VS WAM	12	15011	50	0	48	0
VT VS WAM	12	10000	43	0	45	0
VT VS WAM	12	11000	61	0	42	0
VT VS WAM	12	12000	51	0	52	1
VT VS WAM	12	13000	55	0	43	0
VT VS WAM	12	14000	49	0	39	0
VT VS WAM	72	15011	49	4	43	0
VT VS WAM	72	10000	52	3	50	0
VT VS WAM	72	11000	50	1	51	0
VT VS WAM	72	12000	49	3	47	1
VT VS WAM	72	13000	49	1	46	0
VT VS WAM	72	14000	52	1	46	0
NO ARTILLERY	NA	15011	54	NA	46	NA
NO ARTILLERY	NA	10000	48	NA	45	NA
NO ARTILLERY	NA	11000	55	NA	28	NA
NO ARTILLERY	NA	12000	57	NA	31	NA
NO ARTILLERY	NA	13000	53	NA	32	NA
NO ARTILLERY	NA	14000	44	NA	35	NA

Summaries of ANOVA results are shown in Tables 5.2 through 5.4 . Table 5.2 contains the MOE mean number of WAMs killed by artillery. Note that there is no significant difference between the number of WAMs killed by the artillery scenarios and the non-artillery scenario at an alpha level of .05 (assuming underlying normality of responses).

Table 5.2 Mean number of WAMs killed by artillery

- **MEAN # WAMS KILLED BY ARTILLERY**
  - **PD VS WAM, 36 RDS: 0**
  - **PD VS WAM, 432 RDS: 2.667**
  - **VT VS WAM, 36 RDS: 0**
  - **VT VS WAM, 432 RDS: 2.166**
  - **BASECASE: 0**
- **FAIL TO REJECT THAT**
  - **MEAN1=MEAN2=MEAN3=MEAN4=MEAN5**

Table 5.3 contains the mean number of WAMs killed by direct fire. Again, there is no bottom line difference in the number of WAMs killed by the artillery scenarios and the non-artillery scenario at an alpha level of .05.

Table 5.3 Direct fire MOE

- **MEAN # WAMS KILLED BY DIRECT FIRE**
  - **PD VS WAM, 36 RDS: 60.833**
  - **PD VS WAM, 432 RDS: 56**
  - **VT VS WAM, 36 RDS: 51.5**
  - **VT VS WAM, 432 RDS: 50.166**
  - **BASECASE: 51.833**
- **FAIL TO REJECT THAT**
  - **MEAN1=MEAN2=MEAN3=MEAN4=MEAN5**

Lastly, Table 5.4 shows that for the mean number of red systems killed by WAM there is no bottom line difference in the number of WAMs killed by the artillery scenarios and the non-artillery scenario at an alpha level of .05.

Table 5.4 Mean number of red systems killed MOE

• MEAN # REDS KILLED BY WAM	
–PD VS WAM, 36 RDS:	**39.166**
–PD VS WAM, 432 RDS:	**40.666**
–VT VS WAM, 36 RDS:	**44.833**
–VT VS WAM, 432 RDS:	**47.166**
–BASECASE:	**36.166**
• FAIL TO REJECT THAT	
–MEAN1=MEAN2=MEAN3=MEAN4=MEAN5	

As expected, friendly fire was not a major concern(only three friendly kills occurred in 30 runs). In each case, an SA-8 was killed by 152mm fire. These are simply kills that on the real battlefield could be prevented by safe firing procedures and have no real bearing on WAM.

In summary, WAM minefields cannot be effectively cleared by enemy artillery. Common sense or even a simple mathematical model would have shown this to be the case because of the large area affected by a WAM versus the small size of the weapon.

6. High Resolution Modeling for Assessing WAM Patterns for Area Disruption

6.1 Introduction

A crude simulation was developed to investigate the effects of mine deposition patterns upon the effectiveness of minefields. The effort was undertaken to supplement the JANUS efforts. Because many iterations might be needed because of the stochastic nature of mine-vehicle encounter and the randomness of encounter, etc., a high resolution "first cut" simulation was developed in an effort to gain insight into the problem.

Presently, the simulation does not play groups of attacking tanks, nor does it take into account the difficulty of laying the pattern. Similarly, tactical issues, such as the game-theoretic aspects of revealing information about remaining mine positions, are not considered at this point. These features could be incorporated if there is sufficient interest. Additionally, the program would be more effective with a graphical interface for input of mine positions, and more measures of effectiveness such as average relative distance of ingress into the minefield should be incorporated. Lethality functions other than the "cookie-cutter" could be incorporated, if appropriate.

6.2 Methodology

A BASIC computer program was developed (see Appendix B for a code listing) in which mines located within a "box" 1.0 km on a side are read from an ASCII file. Based upon the assumption there are M mines in the box (M is currently set at 20.) The coordinate system used puts the lower left-hand corner of the box at (0,0), and attacks by tanks hit the bottom of the box first. (Attacks from the left, top, and right hand sides of the box are also considered, in turn.) For the bottom attack case, the entry point of a tank is assumed to be distributed uniformly over the segment from (0,0) to (1,0), and the angle of the direction of motion of the tank (angle between the path of the tank and the bottom of the box) is assumed to be uniformly distributed over the interval $(0,\pi)$. For such a track, the distances from each of the M mines to the closest point of approach of the tank is computed. If the distance is within the lethal radius of the mine (currently set at .1k), an engagement occurs. Each engagement has Pk = P[Hit] * P{Kill/Hit] probability of killing the tank (an aggregated Pk value of 0.3 was used). It is assumed the tank goes in a straight line, and that the mine engagement result events are independent. Only one tank is considered, and no earlier mine-clearing by preceding tanks is considered. If C

mines engage (or could engage) a given tank, the probability it is killed, P_{tk} is computed analytically using the formula

$$P_{tk} = 1 - (1 - P_k)^C \tag{4.1}$$

This is a variance reduction method which should give better estimates than would playing each engagement stochastically as a Bernoulli event given a single P_k value of killing the tank.

The simulation iterates this process a set number of times (presently set at 2500) for attacks on each side of the box. For each set of attacks, the sample mean and standard deviation of the values of P_{tk}, and the standard error of estimate of the mean are printed, together with a histogram of the percent of tracks for which n engagements occurred, n = 0, 1, 2, ..., M.

Some Technical Notes concerning the problem are:

- It can be shown that the average of the P_{tk} values is an unbiased estimator for the expected fraction of tanks entering the box that are killed.

- The random track of a tank has equation (tan(T)x - y = X tan (T), where (X,0) is the point of entry of the tank and T is the angle of the tanks path with the bottom of the box.

- The closest distance from the above tank path to a mine at (x_i,y_i) can be expressed as

$$\text{abs}\left[\frac{(x_i - X)\tan(T) - y_i}{\sqrt{1 + \tan^2(T)}}\right] \tag{4.2}$$

- The program checks each of the M distance squared against the lethal radius squared to see whether the count C of engagements should be incremented.

- The program transforms the array of M mines to different positions to represent the point of views of attacks from the left, top and right sides of the box. The transformation $(x,y) \rightarrow (1-y, x)$ is used in succession (i.e., composition of transformations) to generate points of view from the left, top and right sides of the box. Once the M positions are transformed, the program loops back to perform the set number of iterations against the corresponding side of the box, then the M positions are re-transformed and the set number of iterations are again simulated, and so on until all sides of the box have been considered.

6.3 Limited Results

The simulation was tested with several simple arrangements of mine positions and variations in the input parameters. The output appears to be consistent with results expected.

Results of limited test cases shows there can be considerable differences in the kill probability (and the variance in kill probability) associated with variations in positioning of the mines. Expected fraction killed vary from around .3, for very "bad" deployment patterns, up to about .8 for patterns optimized for a given direction of attack.

The results of five test cases are presented in Table 6.1 and Figures 6.1 through 6.5. Numbers shown in the shaded boxes are P_{tk} values for attacks in the corresponding directions. Table 6.1 contains the x-y locations of the WAM within a 1 km block for the various patterns tests. Figures 6.1 through 6.5 shows plots of the locations. Results from the simulation are shown in Table 6.2. As shown in Table 6.2, either the X or equally spaced pattern or the equal spaced pattern produce the best results if the direction of attack is unknown for the five patterns tested. If the avenue or direction of approach is known, simply stacking the mines perpendicular to the axis of approach produces the highest probability of killing the vehicle.

Table 6.1 X_i - Y_i locations for the various test cases

Case	1	Case	2	Case	3	Case	4	Case	5
X_i (km)	Y_i (km)	X_i (km)	Y_i (km)	X_i (km)	Y_i (km)	X_i (km)	Y_i (km)	X_i (km)	Y_i (km)
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	.05	0.1
0.2	0.15	0.1	0.3	0.1	0.2	0.3	0.1	0.1	0.1
0.2	0.2	0.1	0.5	0.1	0.3	0.5	0.1	0.15	0.1
0.23	0.3	0.1	0.7	0.1	0.4	0.7	0.1	0.2	0.1
0.1	0.9	0.1	0.9	0.1	0.5	0.9	0.1	0.25	0.1
0.14	0.8	0.3	0.1	0.1	0.6	0.15	0.2	0.3	0.1
0.24	0.8	0.3	0.3	0.1	0.7	0.35	0.2	0.35	0.1
0.3	0.78	0.3	0.5	0.1	0.8	0.55	0.2	0.4	0.1
0.9	0.9	0.3	0.7	0.1	0.9	0.75	0.2	0.45	0.1
0.8	0.84	0.3	0.9	0.15	.05	0.1	0.15	0.5	0.1
0.8	0.78	0.5	0.1	0.15	0.15	0.2	0.15	0.55	0.1
0.77	0.7	0.5	0.3	0.15	0.25	0.3	0.15	0.6	0.1
0.9	0.1	0.5	0.5	0.15	0.35	0.4	0.15	0.65	0.1
0.85	0.18	0.5	0.7	0.15	0.45	0.5	0.15	0.7	0.1
0.8	0.2	0.5	0.9	0.15	0.55	0.6	0.15	0.75	0.1
0.75	0.25	0.7	0.1	0.15	0.65	0.7	0.15	0.8	0.1
0.42	0.42	0.7	0.3	0.15	0.75	0.8	0.15	0.85	0.1
0.58	0.42	0.7	0.5	0.15	0.85	0.9	0.15	0.9	0.1
0.58	0.58	0.7	0.7	0.15	0.95	0.25	0.2	0.95	0.1
0.42	0.58	0.7	0.9	0.2	0.5	0.85	0.2	0.5	0.15

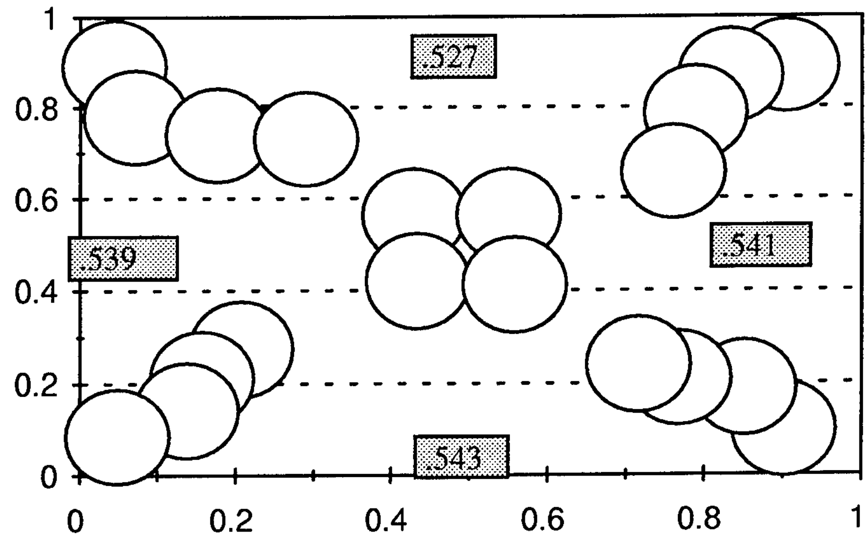


Figure 6.1 Test Case 1 - X pattern

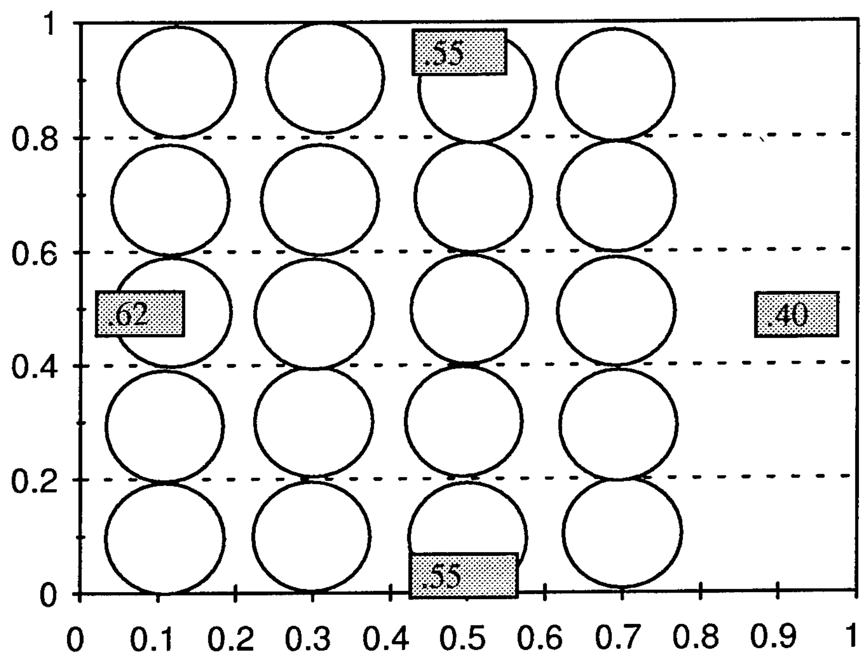


Figure 6.2 Test Case 2 - equal spaced pattern

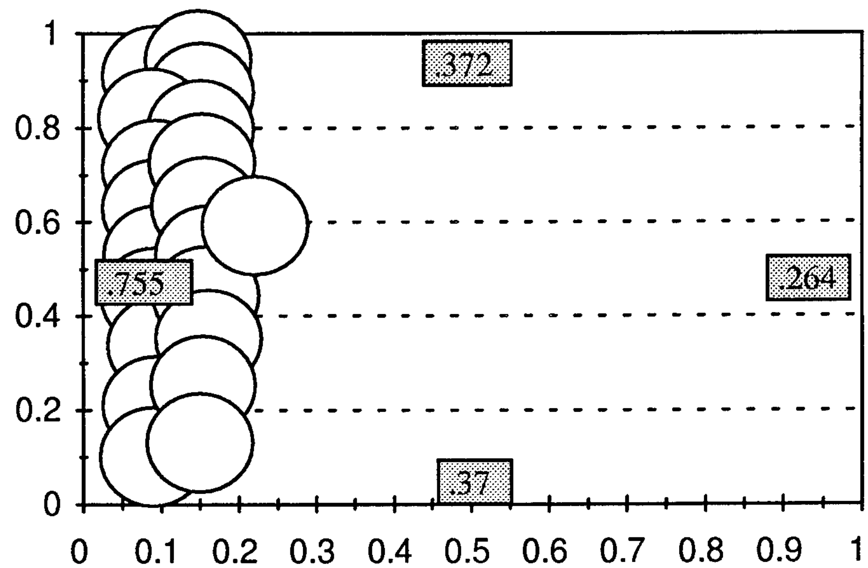


Figure 6.3 Test Case 3 - two column stacked pattern

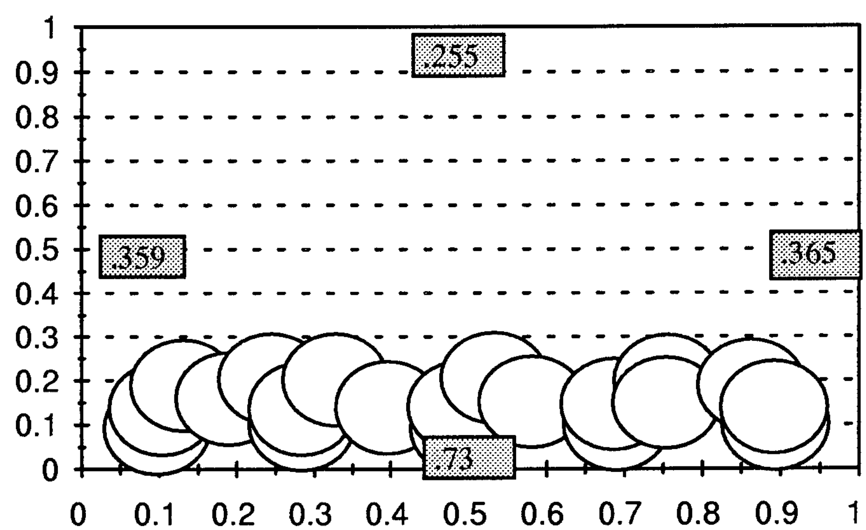


Figure 6.4 Test Case 4 - two row staggered pattern

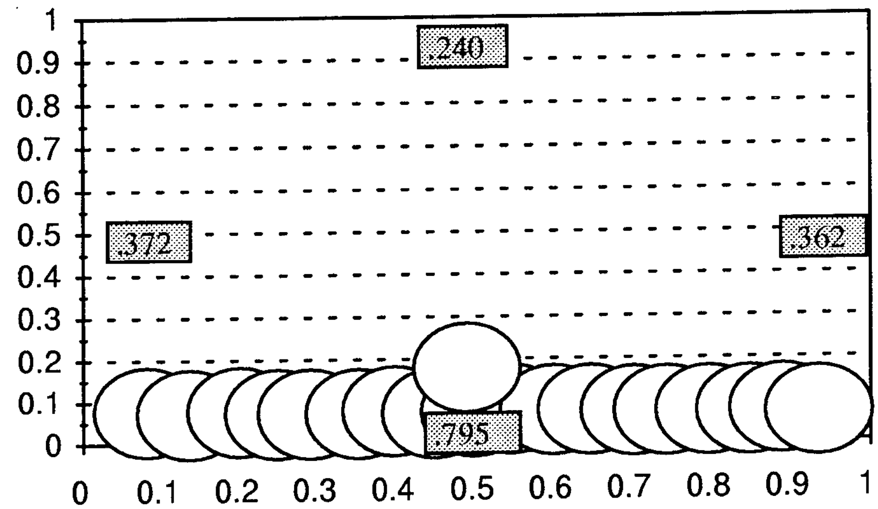


Figure 6.5 Test Case 5 -one row pattern

Table 6.2 Results of high resolution simulation

	Case 1	Case 2	Case 3	Case 4	Case 5
South	0.543	0.551	0.37	0.73	0.795
West	0.539	0.624	0.755	0.359	0.372
North	0.527	0.553	0.372	0.255	0.24
East	0.541	0.401	0.264	0.365	0.362
Average	0.538	0.532	0.440	0.427	0.442

7. Summary and Conclusions

7.1 Summary

The results of four separate studies relating to the effectiveness and deployment doctrine are presented. Three of these studies were conducted using the JANUS combat simulation model. The other centered around the development of a high resolution model to investigate the optimal deployment pattern for the WAM.

The first study was conducted in an effort to develop a methodology to capture the true effectiveness of the WAM. The methodology presented seems to work and provides realistic results. However, more research is needed. Verification and validation of the results should be performed beyond a subjective assessment by the study team. If a combined arms combat simulation model study is required to support fielding of WAM, all results should be viewed with the understanding of the effect input data has on the results. Ideally, JANUS should be modified to correctly play WAM in lieu of "tricking" the model by using an indirect fire representation. Lastly, some type of assessment of the true acquisition capability of a threat tank must be developed in two scenarios: unopposed and during breaching of a cover obstacle. Effectiveness of the WAM can only be quantified by bounding the problem with these two extremes.

The study to assess optimal patterns for area denial using JANUS produced mix results. The large increase in effectiveness of the X-pattern over the random pattern was probably a product of the scenario (angle of attack, actual vehicle approaches, etc.,). In order to quantify the effectiveness of the various patterns within JANUS, more detailed studies should be conducted. Also, more than 5 repetitions are needed for each design point. Sensitivity analysis of the high resolution modeling showed that several thousand are needed. If the angle of approach had been varied, results similar to those produced by the high resolution simulation would probably be produced. Ideally, JANUS should not be used to assess locations of WAM for deployment doctrine.

The artillery study conclusively showed that indirect fire has little effect on WAMs. A simple mathematical exercise would have produced a similar results because of the small size of the WAM relative to the large area covered. In summary, artillery can kill WAM, but apparently trying to kill WAM in a large general area is like trying to find the proverbial "needle in a haystack." In a real battle, a Forward Observer might have a slight idea of location in general of a WAM minefield, but according to the findings of this study, there are no effects on WAM from Area Fire, even if an entire division artillery asset was used against WAM. Concerning whether artillery have residual benefits on a WAM breaching force, it was concluded that artillery does not benefit either the number of breachers killed, the number of WAMs killed by direct fire, and introduces a slight extra danger to a

breaching force of friendly indirect fire. The use of artillery to confound the sensors of WAM by rolling artillery directly ahead of a concurrent breaching force should be investigated.

The high resolution simulation shows a lot of promise as an important analytical tool for deploying the WAM. This simple model could easily be modified to include various vehicle formations, game theory aspects of minefield encounters, etc. Also, with a minimum amount of effort, a graphical interface could be developed to help input WAM locations. The preliminary results from the high resolution simulation showed that for an unknown avenue of approach the X-pattern and uniformly spaced (would also probably be representative of randomly spaced non-overlapping WAMs) produce a similar value of effectiveness. Also, if the avenue of approach is known a significant increase in effectiveness can be achieved by using a different pattern.

7.2 Conclusions

Several major conclusions can be derived from this study. These are:

- Artillery resources cannot significantly reduce the effectiveness of a WAM minefield.

- Properly portraying WAM in JANUS is not a trivial task. To ascertain the effectiveness of the WAM, the problem should probably be bounded as presented in this report.

- The pattern used to deploy the WAM can significantly enhance the effectiveness of the WAM. However, JANUS is not the analytical tool that should be used.

- A specially coded simulation will provide the needed information (i.e., effectiveness as a function of deployment pattern) required to properly analyze deployment patterns for the WAM.

8. References

Army Times, "Defense Trends: Putting the WAM-my on Enemy Tanks," November 23, 1992.

Headquarters, Department of the Army, "Mine/Countermine Operations," Field Manual 20-32, July, 1992.

U.S. Army Armament Research, Development, and Engineering Center, "Smart Munitions Strategic Plan," 1993.

Appendix A. Acronyms and Abbreviations

Abbreviation	Description
ANOVA	Analysis of Variance
ARDEC	U.S. Army Armament Research, Development, and Engineering Center
CASTFOREM	Combined Arms and Support Task Force Model
CDF	Carleton Damage Function
COEA	Costs and Operational Effectiveness Analysis
DA	Department of the Army
DoD	Department of Defense
DSE	Department of Systems Engineering
DP	Design Point
EFP	Explosively Formed Penetrator
FER	Fractional Exchange Ratio
FM	Field Manual
HEMTT	Heavy Expanded Mobility Tactical Truck
IR	Infrared
LER	Loss Exchange Ratio
MOE	Measures of Effectiveness
MRR	Motorized Rifle Regiment
PD	Point Detonating
Ph/Pk	Probability Hit/Probability Kill
SWA	Southwest Asia
TIP	Troop In Prone
TRADOC	Training and Doctrine Command
USAECS	U.S. Army Engineer Center and School
USMA	U.S. Military Academy
VT	Variable Time
WAM	Wide Area Mine

Appendix B. Source Code Listing for WAM Deployability Analysis Model

```
5 REM PROGRAM TO SIMULATE LINEAR TRACKS AGAINST MINES STORED IN "CASE NAME"
7 REM      CONSIDERS FOUR ATTACK ENTRIES--BOTTOM, RIGHT, TOP, LEFT
10 RANDOMIZE TIMER
20 SSKP=.3  :ITER=2500 :RADS=.01 :ATK=1 :  REM CHANGEABLE PARAMETERS
30 DIM L(20,2), CT(20), AT$(4)
35 AT$(1)="BOTTOM":AT$(2)="LEFT":AT$(3)="TOP":AT$(4)="RIGHT"
40 INPUT "CASE NAME, # MINES";I$, M
50 OPEN I$ FOR INPUT AS #1
60 FOR N=1 TO M
70      INPUT #1,L(N,1), L(N,2)
80 NEXT N
90 CLOSE #1
100 KB=0:KBS=0
105 FOR I=1 TO ITER : REM MAIN SIMULATION LOOP, OVER TRACKS
110     X=RND:T=RND*3.141593 :C=0
120     FOR N=1 TO M : REM COUNT NUMBER OF ENGAGEMENTS, GIVEN TRACK
130            D=((L(N,1)-X)*TAN(T) - L(N,2))/SQR((TAN(T))^2 + 1)
140            DS=D*D: IF DS <= RADS THEN C=C+1
150     NEXT N
160     K=1-(1-SSKP)^C
170     KB=KB+K: KBS=KBS+K*K: CT(C)=CT(C)+1
175 IF INT(I/200)=I/200 THEN PRINT "+";
180 NEXT I
190 KB=KB/ITER: KE=SQR((KBS-ITER*KB*KB)/(ITER-1))
195 LPRINT:LPRINT:LPRINT "RESULTS FOR ATTACK FROM ";AT$(ATK)
200 LPRINT: LPRINT "EXPECTED FRACTION KILLED IS ";INT(KB*1000)/1000
210 LPRINT "    STANDARD DEVIATION OF FRACTION IS";INT(KE*10000)/10000
215 LPRINT "          STANDARD ERROR OF ESTIMATE IS";SQR(KB*(1-KB)/ITER)
220 LPRINT "% OF TRACKS HAVING N ENGAGEMENTS (*=2%):"
225 LPRINT:LPRINT " N","|";"    10%  20%  30%  40%"
230 FOR N=0 TO M:
235 LPRINT N,"|";
240     FOR J=1 TO INT((CT(N)*50)/ITER):LPRINT "*";: NEXT: LPRINT
250 NEXT N
255 IF ATK>1 THEN GOTO 280
260 LPRINT:LPRINT:LPRINT "ABOVE RESULTS FOR MINES LOCATED AS FOLLOWS:"
265 LPRINT: LPRINT " #"," X"," Y"
270 FOR N=1 TO M:'LPRINT N,L(N,1),L(N,2): NEXT
280 ATK=ATK+1:IF ATK>4 THEN END
290 FOR N=0 TO M
300     H=L(N,1): CT(N)=0
310     L(N,1)=1-L(N,2)
320     L(N,2)=H
330 NEXT N
340 LPRINT:LPRINT:GOTO 100
350 END
```